ST. LOUIS PUBLIC LIBRARY
AUG 31 1945

TRANSACTIONS OF THE ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909

INCORPORATED 1930

CONTENTS

Page

Daylight and Its Penetration Into the Sea, by Dr. W. R. G. Atkins, O.B.E., F.Inst.P.,F.R.S. *(Member)* - 133

Proceedings at the Annual General Meeting - - - - - 143

Additions to List of Members - 146

VOLUME X.—No. 7
JULY, 1945

32 VICTORIA ST
LONDON, SW1

SESSION 1944—1945

THE I.E.S. COUNCIL

***President*:**—E. STROUD, F.I.E.S.

***Vice-Presidents*:**—H. C. WESTON, F.I.E.S.; D. CHANDLER, F.I.E.S.; HOWARD LONG, M.I.E.E., F.I.E.S.

***Members of Council**:**—

Elected Members:—

H. S. ALLPRESS, P. V. BURNETT, J. B. CARNE, H. E. CHASTENEY, W. J. G. DAVEY, W. E. J. DRAKE, S. I. ELLIS, F. S. ETTE, W. HETHERINGTON, J. G. HOLMES, W. C. HUSTON, R. MAXTED, F. F. MIDDLETON, E. G. PHILLIPS, C. W. M. PHILLIPS, R. P. SAYERS, GEO. SMITH, W. R. STEVENS, J. F. STANLEY, J. M. WALDRAM, DR. J. W. WHITAKER, T. WILKIE, G. T. WINCH.

Ex Officio Representatives of Areas:—

Midland Area: A. J. PASHLER
Nth.-East. Area: E. C. LENNOX
Nth.-West. Area: N. C. HODSON
Nth.-Mid. Area: E. C. WALTON
Scottish Area: E. M. HOOD
Sth. Wales Area. PROFESSOR T. DAVID JONES
Western Area: E. J. IRELAND

***Hon. Treasurer*:**—N. V. EVERTON.

***Hon. Secretary*:**—J. S. DOW.

*In addition, all Past Presidents of the Society are *ex-officio* Members of Council.

***Secretary*:** RAYMOND PYE.

Committees

GENERAL PURPOSES COMMITTEE: E. Stroud *(President)*, N. V. Everton *(Hon. Treasurer)*, J. S. Dow *(Hon. Secretary)*, R. O. Ackerley, H. Buckley *(Past-Presidents)*, H. C. Weston, D. Chandler *(Vice-Presidents)*; Howard Long *(Midland Area)*, E. J. Ireland *(Western Area)*.

PAPERS COMMITTEE: H. Buckley, P. V. Burnett, J. G. Holmes, R. Maxted, F. C. Smith, W. R. Stevens, E. C. Walton, H. C. Weston.

LIGHTING RECONSTRUCTION *(ad hoc)* COMMITTEE:—R. O. Ackerley *(Chairman)*, Dean Chandler, Dr. S. English, Percy Good, W. J. Jones, Dr. C. C. Paterson, F. C. Smith, Dr. J. W. T. Walsh, Sir Duncan Wilson.

AREAS JOINT COMMITTEE:—

Representatives of Areas: *(Midland Area)* A. J. Pashler, *(North Eastern Area)* E. C. Lennox, *(North-Western Area)* N. C. Hodson, *(North-Midland Area)* E. C. Walton, *(Scottish Area)* E. M. Hood, *(South Wales Area)* B. C. Wilkins, *(Western Area)* E. J. Ireland.

Council's representatives: F. C. Smith, R. O. Ackerley, H. Buckley.

(N.B.—The President, Hon. Secretary, and Hon. Treasurer are *ex-officio* members of all committees.)

DAYLIGHT AND ITS PENETRATION INTO THE SEA

By Dr. W. R. G. ATKINS, O.B.E., F. Inst. P., F.R.S. *(Member)*

(Address delivered on Tuesday, May 15, 1945.)

Though I have spent many years studying natural illumination it was only a few years ago that I became a member of this Society, being attracted to it by the great interest of the papers published in the "Transactions." It came, therefore, as a great surprise to me, one of the junior members, that I should be honoured by the request to give this lecture, and I desire to thank you most sincerely for asking me. That I am able to do so at all is very largely due to the help which I have received for more than 20 years from my old college friend, Dr. Horace Poole, Chief Scientific Officer and Registrar of the Royal Dublin Society, with whom I have worked during this long period.

Introduction.

Daylight may be measured by observing the electric current generated by its incidence upon a photo-electric cell, but only with accuracy if certain conditions are fulfilled. The cell may be a photo-tube with sensitive surface (cathode) or a metal plate coated with a semi-conductor, such as selenium; those of this type are known as barrier layer or rectifier cells. When Dr. H. H. Poole and I took up photo-electric photometry in 1924 the first stable cell we obtained was a vacuum photo-tube with a potassium cathode. It required 318 kilolux to produce one micro-ampere when mounted under a flashed opal diffusing disc. The international unit of illumination is the metre candle or lux, namely, that produced by one standard candle at one metre, but for daylight the kilolux is a convenient multiple. To measure light under water we used a gas-filled Kunz cell with a sensitized surface of potassium hydride; this had to be standardized at short intervals against the less sensitive stable cell. By 1933 it was possible to get a vacuum cell with a caesium film on silver oxide which gave one micro-ampere for 40 lux. By 1935 a large selenium rectifier cell, under opal as usual, gave 1μA for 1.32 lux.

In sunlight sodium and potassium cells give a maximum response in the violet; that of the 1933 type cathode is in the red. But the selenium maximum is in the yellow and its sensitivity curve is rather like that of the eye, though extending further towards both the red and blue ends of the spectrum. A special green glass filter brings this cell into close accord with the eye (Fig. 1).

Since the only source comparable to

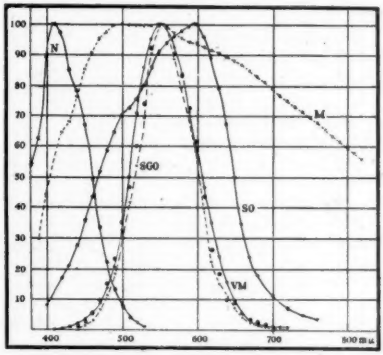


Fig. 1. The ordinates are percentages, the abscissae wave-lengths of light, M shows the distribution of energy in mean noon sunlight; N the spectral sensitivity curve of a vacuum sodium photo-tube under opal, in sunlight; S0 relates similarly to a selenium rectifier cell and SG0 to the same with green filter under opal, while the crossed circles concern this cell and filter without the opal, VM is the standard sensitivity curve for the eye, but in mean noon sunlight instead of an equal energy spectrum.

daylight in colour-temperature and intensity is the electric arc, we standardized the sodium and potassium cells against an arc, using the results of Allen and Forrest, as quoted by Macgregor-Morris, to obtain the intensity of the arc, namely 164 c.p. per sq. mm. per amp. at 45 degs. to the

surface of the crater. The adjustment of the arc was facilitated by projecting its image upon a white wall with ruled grid. Later these cells, the selenium and other types, were standardized in Abbot's mean noon sunlight, obtained using a uniplane filament sub-standard tungsten lamp and the appropriate Davis-Gibson double filter cell and solutions. Closely concordant results were obtained when cells standardized by the two methods were used to measure mixed daylight. But in determining the ratio of sunlight to skylight the cells with a high sensitivity to red naturally gave greater values than those of predominantly blue sensitivity.

Using colour filters of known transmission and a source of known colour temperature it was also possible to obtain approximate values for the energy in the spectral bands isolated, calibrating in micro-watts per sq. centimetre per micro-ampere.

Though a well designed vacuum photo-tube gives a rectilinear relation between current and illumination even up to the intensity of direct sunlight, with rectifier cells the relation holds only for low illuminations. Each cell has to be tested for curvature before use, and the differences between the various types and sizes are so great that no reliance can be placed upon results obtained with an uncalibrated cell. In every case however, the curvature is minimised by using a low-resistance measuring instrument, preferably of 10 ohms, together with a shunt designed to maintain the effective resistance constant. It is even better to use the Campbell-Freeth circuit, in which, as no current flows, the effective resistance is theoretically zero. Poole has modified this for use at sea with a telephone as null-point indicator, instead of a galvanometer.

The Intensity of Natural Illumination.

(a) *As received on a horizontal surface.*—Few people realise the enormous range of intensity experienced in the open. This is due to the great adaptability of the eye. We can see to get about fairly well in clear starlight; there is no difficulty at all in good moonlight, yet this rarely exceeds 0.1 lux. Just before sunrise or just after sunset in clear weather the vertical component of the skylight, namely, that received upon a horizontal surface, is about 700 lux (Fig. 2). But at noon on a bright December day it may be 20 kilolux; or 95 kl. with sun at 45 deg., rising to a June maximum of 122 kl. for 63 deg. in England, or to 145 kl. in Ceylon with vertical sunlight (Fig. 3). Bright sunlight is thus more than one million times as intense as moonlight.

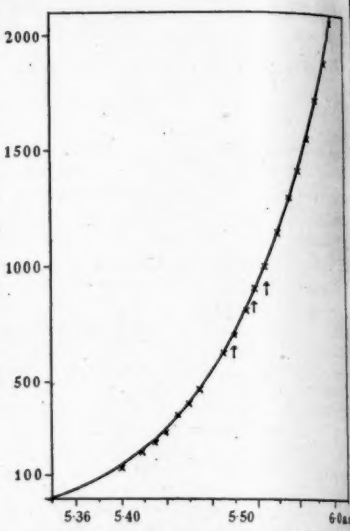


Fig. 2. Variation of the vertical illumination in lux, as found using a selenium cell under opal, before and after sunrise, in Ceylon. The first arrow indicates the appearance of the sun; the second when the full disc was visible; the third when sun was clear of light cloud.

Furthermore, the luminous efficiency of both sunlight and skylight is very high. Using a selenium cell standardised in mean noon sunlight to measure illumination and a Moll solarimeter to determine the energy simultaneously, average values for blue sky gave 125.7 lumens per watt, for sunlight 90.8, for sun and sky 107.8, as compared with Kimball's determinations in U.S.A., which for sun and sky gave 105.1, plus or minus 5 per cent. as found visually. Closely similar values were obtained using

the special green filter to render the selenium cell response almost identical with that of the eye.

The foregoing values of the luminous efficiency may be compared with the 668 lumens/watt given by Hyde, Forsythe, and Cady for radiation of maximum visibility, taken here for $\lambda = 0.556\mu$. As against these, our own measurements with the selenium cell on the open carbon arc, in a position in which the positive carbon is quite unscreened, give for the luminous efficiency about 28 lumens/watt,

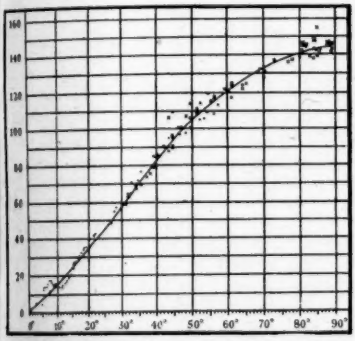


Fig. 3. As Fig. 2, but vertical illumination is in kilolux, plotted against solar altitude. The sun was clear, with a few clouds at times, especially below 40 kl. Observations of April, 1935, are shown by crosses, those of September by dots.

the efficiency of the source as derived from the input power being about one-half as great.

(b) *As received at a point.*—In order to measure light received from all directions, a Weston selenium rectifier cell, mounted under opal flashed diffusing glass, was set in the metal seat or gallery below a globe such as ordinarily supplied to house an electric lamp. This doubly diffused light was not entirely independent of the altitude and azimuth of the source. Such independence was, however, secured by mounting over the plane opal an additional hemispherical diffusing surface; for this, one end of an old Ediswan "Fullolite" electric lamp bulb served when the volatilized tungsten had been removed with fused potassium nitrate. The globe photometer was standardized in the open against a similar Weston cell measuring the vertical component of daylight and, by difference, that of sunlight and skylight; the direct light of the sun was screened from each by a small circular disc held at a distance.

Since the globe photometer receives sunlight at normal incidence, the purely geometrical effect of obliquity is eliminated. The reading, therefore, may remain nearly constant throughout the middle of the day as in Figure 4; such an effect is similar to the illumination received by the leafy crown of a tree considered as a unit. But as the zenith distance of the sun increases, the air mass traversed by the sunlight grows greater in proportion to the secant of this angle, so the illumination is correspondingly reduced.

Theoretically, with a uniform sky, the light received at a point should have twice the intensity of that received upon a horizontal surface, and

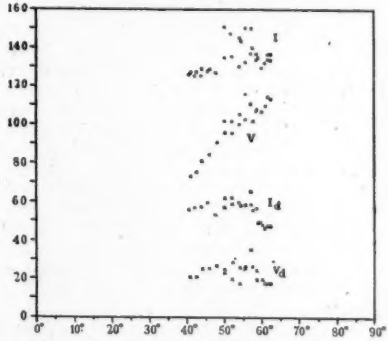


Fig. 4. Readings of daylight with globe photometer. Ordinates and abscissal as in Fig. 3, as in which V shows the vertical component of daylight; V_d concerns diffuse light only. I shows the intensity of daylight as received upon the globe photometer at Plymouth, 24th June, 1936, with sun clear, clear blue sky with white clouds. The crosses I_d relate to diffuse light.

four times that falling on a vertical surface. But on account of reflection from the sea and the ground the total intensity was usually 2.3—2.6 that of the vertical component, the photometers being mounted on the parapet of the flat roof of the laboratory overlooking Plymouth Sound. Occasionally a white cloud raised the

vertical illumination, so that a value slightly under 1.9 was obtained for the ratio.

Measurement of the Amount of Light Received Daily.

The globe photometer gives a measure of the luminous flux integrated with respect to space. The physiologist, however, requires a time integration also.

Using a vacuum cell to measure either the vertical or total illumination, it is possible to use the current to deposit copper on platinum; the process may be termed photoelectrolysis. The copper is then redissolved and estimated colorimetrically, a method of great delicacy. A large sodium cell, such as used in recording daylight, would deposit about 0.1 mg. in a winter day and about 1 mg. during a day in summer. One of the modern (1933) thin film cells would, however, give about twenty times as much copper.

Alternatively, one may expose a photo-sensitive solution, and note its decomposition in a given period. The most satisfactory mixture appears to be one of oxalic acid catalysed by uranium sulphate. The photolysis is due to the blue end of the spectrum, but is not limited to the ultra-violet. The method was standardized against a photoelectric cell and, with tubes suspended in the rigging at sea, August 17, 1928, averaged 25.8 kilolux for the horizontal component of the illumination, and September 18 averaged 23.6 kilolux. The results are probably too great as however the tubes swung out of the vertical, the illumination received must have been increased. The period was sunrise to sunset. Similar exposures can be made using horizontal tubes or spherical flasks.

Records of the photoelectric current had been obtained using photographic paper to register the galvanometer movement, but the advent of the Cambridge Instrument Company's "thread recorder" and the Burt vacuum sodium cell rendered it possible for us to get immediately visible records of daylight, as received from the opal-flashed glass surface of the photometer, set horizontally. The sodium cathode of this cell is of remarkable stability and is produced by electrolysis of the glass. Its constancy may be judged from the following:—

TABLE I.

Daily maximum current, in microamperes, from Burt sodium cell No. 299, on front parapet of roof in Plymouth. Bright days in March, 1933, were compared with the same dates in other years.

Day.	1930.	1933.	1937.
18	23.85	23.90	24.10
21	23.90	22.75	10.70
22	22.60	22.40	23.90
23	9.60	23.50	23.00
24	22.85	21.00	25.30
30	26.00	26.70	26.70

Records were obtained daily, with but few exceptions, till March, 1941, when heat from the burning building reduced the sensitivity of the cell and hose-water put the recorder temporarily out of action. By measuring the areas of the daily curves with a planimeter the vertical illumination integral was obtained and is given in kilolux hours a day. Mean daily values for the years 1930-1937 inclusive are respectively as follows: 412, 326, 309, 310, 350, 311, 309, 307. With such a set of figures one would naturally suspect an initial loss of sensitivity in the photometer, but it has not been possible to detect any. The first three months of 1930 were entirely normal; but in April and from June till October the 1930 values were maxima for the years. Results obtained by Aurén in Sweden, using a photographic recorder for his potassium cell, were, however, found to give similar, though rather lesser, wide divergences. These show no correlation with any of the usual meteorological observations, but a careful sifting of the records over the 11 years is now in progress. It must be remembered that we are measuring the vertical component of the light, and that this is influenced by atmospheric scattering and reflection from clouds. Furthermore, during a spell of fine, sunny weather the daily charts are apt to give a decreasing area, due to an increase in pollution from dust and smoke. There is, finally, the possibility that the small variations in solar radiation, as observed by Abbot

and his co-workers, measuring the output over the whole spectrum, may be considerably larger in the short wave end; the Burt cell, in a mean noon sunlight spectrum, exhibits a sharp maximum at 0.41 μ, namely, in the violet, where the eye is of a very low sensitivity.

Table II. has been prepared to show how the illumination is distributed throughout each year, see also Fig. 5.

TABLE II.

Vertical illumination integrals calculated for each calendar month as a percentage of the total for the year at Plymouth

	1930.	1932.	1934.	1936.
January ...	1.71	1.91	1.47	1.88
February ..	2.63	3.46	3.87	3.57
March	6.51	9.27	8.09	7.83
April	13.63	13.38	11.70	12.22
May	14.83	15.23	17.72	17.54
June	14.45	17.17	15.74	15.05
July	16.12	13.40	14.33	13.30
August ...	13.44	10.42	11.50	12.25
September	9.00	6.87	8.47	7.79
October ...	4.50	5.45	4.20	5.02
November .	1.91	1.84	1.80	2.11
December ..	1.27	1.60	1.11	1.44
Winter half	18.53	23.53	20.54	21.85
Summer half	81.47	76.47	79.46	78.15

December is always the month receiving least light, but May, June, or July may have the greatest amount, usually May at Plymouth. Also it is seen that the six leafy months get from three-quarters to four-fifths of the total vertical illumination each year.

Sky Brightness and the Daylight Factor

By interposing a small disc between photometer and sun it is possible to cut off direct sunlight. One may thus find the vertical component of the diffuse light of the sky, and the total intensity is twice this. Since one hemisphere contains 20,628 square degrees, one obtains the average sky brightness in lux per sq. deg. by dividing the vertical component by 10,314. Thus when $V_d = 10$ kl. one obtains 0.97 lux per sq. degree of sky; and under a uniform sky a pure white uniformly diffusing surface is indistinguishable from the sky. Such a sky brightness would therefore produce a snow brightness of close to one lambert. Measurements were made with a selenium cell and telescope at azimuths 0 deg., 30 deg., 45 deg., 90 deg. and 180 deg. with respect to the sun from horizon to zenith. With a clear blue sky the 90 deg. azimuth

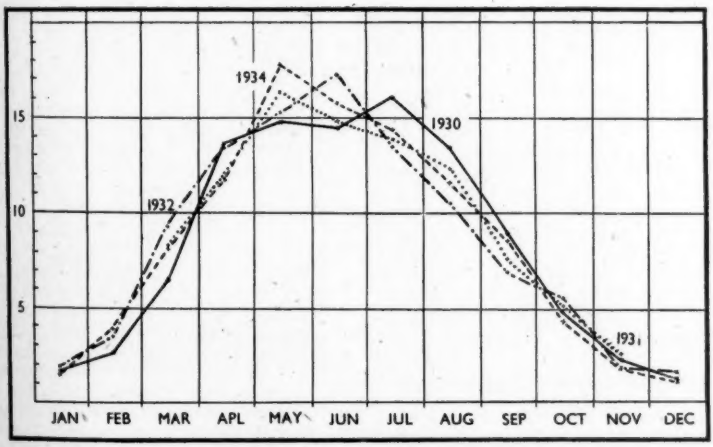


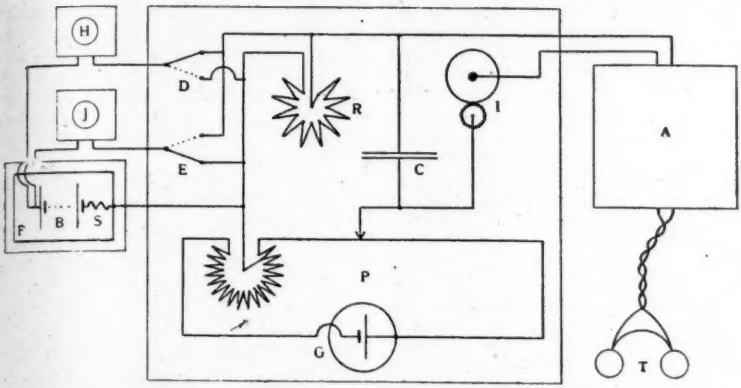
Fig. 5. Distribution of daylight throughout the year. Ordinates show percentages of the yearly total of the vertical illumination integral (measured in kilolux hours), received each month, as in Table 2.

might give a nearly straight line. The 180 deg. azimuth was the least bright. Usually the minimum brightness was at the zenith. A sky almost covered with light cloud gave up to 4 or 5 lux per sq. deg., or even up to 12 for observations in the same vertical plane as the sun.

It is thus possible to obtain the daylight factor, namely, the percentage of the similarly received illumination from the whole sky, from a knowledge of the sky brightness, or alternatively by measuring the vertical diffuse illumination at the point indoors and in the open at the same time. This is the best way of assessing the natural illumination of a room or of a wood. When in the latter there is much undergrowth, and progress is difficult, the daylight factor may be about 15-20 per cent., as in an oak wood. But in a holm oak wood one can walk easily over ground ivy or dead leaves, with about 2 per cent. In a conifer wood progress is unimpeded over pine needles with under one per cent. daylight factor. Where much of the light is transmitted the spectral character of the sky light is also modified by the chlorophyll absorption bands, so that green and deep red predominate. The illumination in a wood is regulated almost entirely by sky brightness, and save in a sun-fleck the temporary obscuration of the sun by a small cloud has little effect. For such studies, when the wind causes trees to sway, the neon tube photometer, introduced by J. H. J. Poole in 1928 (several years before Rentschler described it in U.S.A.), has been useful, as it also is for measuring the illumination immediately below the surface of the sea. In this method the photoelectric current charges a condenser which is discharged through the neon lamp. The rate of flash is rectilinearly proportional to the charging current and a suitable rate is obtained by selection from a series of condensers.

The Measurement of Submarine Illumination

This problem resolved itself into the measurement of small electric currents aboard a drifter-trawler in which movement and a moist atmosphere introduced many experimental difficulties. No galvanometer sensitive to one millimicro-ampere per scale division will stand the motion, and the use of an electrometer has special difficulties on a little ship. Rapidity of action is moreover an essential. Again, one cannot use a method involving strain on the eyes, for it was necessary to work sometimes for as many as six hours continuously under conditions which were often decidedly trying. Horace Poole's ingenuity however rose to the occasion and with standard types of apparatus and a little "Meccano" he produced an instrument which, with some modifications required for use with rectifier cells, has stood the test of twenty years' service. The photo cells are mounted, one on the deck house roof in gimbals, the other in a water-tight metal box swinging above the water from a spar lashed to the boom directly over the stern. The latter is pointed towards the sun, when visible. Both cells are under opal flashed glass, beneath which colour filters can be placed. The leads are connected, in succession, to a high resistance and the drop in potential across the latter is measured using a Tinsley hydrogen-ion potentiometer. The detection of the point of balance is effected by means of a telephone; this involves having an interrupter and amplifier. Initially interruption was effected by a platinum contact operating as a buzzer in a metallic fork. This was soon replaced by a Meccano clockwork which rotated a smooth wheel against a toothed wheel. The amplifier is adjusted in sensitivity so that silence is attainable as a fairly sharp minimum; this can be read to 0.5×10^{-9} amp. in the most sensitive position. In the drier air of the laboratory a higher resistance can be made to yield a greater sensitivity. When the advent of the rectifier cell necessitated the use of a low resistance circuit Poole adapted the Campbell-Freeth circuit, introducing a small correction for the fact that the potentiometer is now operated slightly out of balance. In tolerably good conditions it is possible to make up to eight determinations per minute, alternating between the air and the under-water photometers. Balance is obtained with the eyes shut and the



A, amplifier; B, high tension batteries; C, condenser; D and E, switches; F, metal box, insulated from outer wooden one; G, guard plate, on which stands potentiometer accumulator; H, vacuum photo-electric cell in deck photometer; J, gas-filled photo-electric cell in submarine photometer; I, interrupter; P, potentiometer; R, 100,000 ohm resistance, sub-divided; S, 10,000 ohm safety resistance; T, telephone.

Fig. 6. Apparatus for the measurement of submarine illumination.

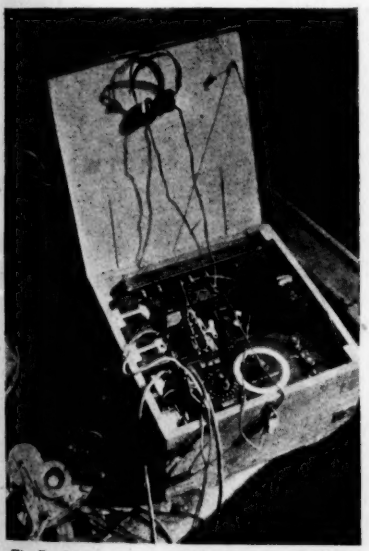


Fig. 7. A general view of the apparatus illustrated in Fig. 6. On the left is the submarine photometer with cord operating shutter, above is part of deck photometer. The potentiometer is in the front of the instrument case, with interrupter in centre and amplifier on the back wall.

reading is then called out to one of the crew. The early form of the apparatus is shown schematically in Fig. 6 and in the photograph in Fig. 7.

A more elegant model with specially good insulation was made by Messrs. H. Tinsley and in 1931 Mr. D. C. Gall and I installed it in the U.S.A. Research Ship Atlantis, in which Dr. G. L. Clarke, of Harvard, operated it across the Atlantic.

The apparatus described served for the determination of the extinction coefficient of sea water at a number of stations and throughout the year. Most work was done 20 miles out at International Hydrographic Station, England No. 1, referred to as E1, where the depth is a little over 70 metres, at which it is safe to operate the photometer without risk of bumping.

The extinction coefficient is a comprehensive term, including the effects of true absorption and of scattering. The latter is, for particles comparable in size with the wave-length, inversely proportional to the fourth power of the wave-length. It accordingly has most effect upon the short-wave end. But large particles scatter non-selectively. True absorption is great in the infra red, marked

in the red and reaches a minimum in the blue. Very pure sea water consequently appears blue when seen against a white disc (the Secchi disc) lowered into it. Coastal water ordinarily appears blue-green or greenish, verging towards a muddy brown in which the very low transmission may have a maximum in the red as found by Cooper and Milne using short water columns in the Pulfrich photometer.

The coefficient is obtained from consecutive observations giving the illumination as percentages of that immediately below the water, the subsurface illumination; denoting the percentages as p_1 and p_2 at depths d metres apart, then the extinction coefficient per metre is

$$2.30\ (\log_{10} p_1 - \log_{10} p_2)/d.$$

In fairly clear coastal water blue light is reduced to half its subsurface intensity at a depth of 5 metres; the intensity is again halved at 10 m. and so on. This corresponds to a coefficient 0.14.

Fig. 8 gives results obtained with a selenium rectifier cell and colour filters, beneath opal flashed diffusing glass. From this one can read off the depths at which light of different colours is reduced to, say, 10 per cent., 1 per cent, and 0.1 per cent. The heavy extinction of the red and the relatively great penetration of the green is at once evident. But Beebe, descending to half a mile (800 metres) in his bathysphere found in the clear water east of the West Indies that the residual light was a wonderful blue, fading to a greyish as he passed beyond the limit at which the eye can perceive colour.

It has been possible to measure green and blue light at E1 down to 70 m., namely bottom, but with a red filter cutting off sharply at 600 mμ no measurements could be obtained below 20 m. Even over the 15-20 m. range the extinction coefficient showed a marked diminution as compared with 10-15m., viz., 0.284 and 0.379 respectively on account of

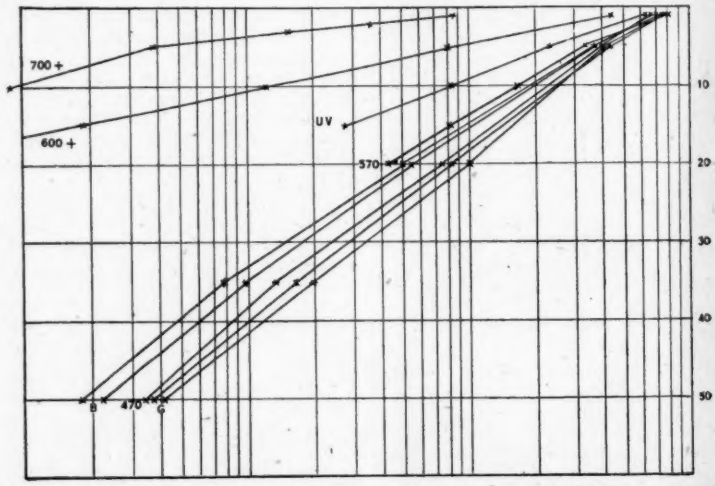


Fig. 8. Showing the reduction in intensity of daylight at various depths of sea water. The ordinates are depths in metres, the abscissae percentages of the sub-surface illumination shown on a logarithmic scale. The graphs relate, from above downwards to light over 700 mμ (deep red); 600 upwards (red); ultra-violet (330-420); a yellow band, 550-580; duplicate determinations, with an interval of one hour for blue, 330-480; a blue green band, 455-480; duplicate determinations, with an interval of 3½ hours, for green, 480-580, max. at 530 mμ. Locality, ½-mile E. of Eddystone, 21/9/'36. Uniform overcast sky, visibility ½-mile. Slight swell, wind light.

the action of the water in cutting off the longer wave-lengths.

In the more turbid water near Plymouth Sound Breakwater the depths of penetration are, of course, much reduced; thus for red (600 +), green, and blue the depths for reduction to 1 per cent. are respectively 4.6, 10.7, and 6.3 metres, as against 10.5, 41, and 34m. near the Eddystone. In the turbid water of the estuary, the Hamoaze, Cooper and Milne found that the intensity of incident daylight (weighed to be correct for mean noon sunlight) was reduced to 1 per cent. within 4m., often in less than 2m., and at low water, when the rivers were in spate, in less than 0.5m.

Just before the war we used a cubical photometer with six photocells to study the angular distribution of under-water illumination, and found that the average angle with the vertical was 36-40 degs., irrespective of solar altitude or state of the surface or sky.

Some Biological Effects Produced by the Light that Enters the Sea

It is well known that the sea produces a vast weight of fishes every year. Relatively few realise that these fishes are dependent ultimately upon plants for their sustenance, just as cows are immediately dependent upon grass. Still fewer know that the plants concerned are mostly microscopic in size, the freely floating diatoms, peridinians, and flagellates, of which the diatoms are the most important. But to count them!—in the words of Spenser—

O what an endlesse worke I have in hand,
To count the sea's abundant progeny,
Whose fruitful seede farre passeth those in land,

. . . . . .

Then to recount the sea's posterity
So fertile be the flouds in generation,
So huge their numbers and so numberlesse their nation.

An estimate can, however, be made by chemical means. The early German work of Brandt and his school showed that when the seasonal variation in the minor constituents of sea water—the nutrient salts—was followed through, the exhaustion of the nitrogenous compounds appeared to set a limit to plant growth. Their analyses proved a seasonal diminution in phosphate, but never complete exhaustion at any depth. I was, however, able to show in 1923 that the phosphate in the upper levels of the sea was completely used up every spring, and that the German workers had missed this because their chemical analyses had included arsenates and arsenites with phosphate. In early spring the phosphate content of the whole water column, surface to bottom, diminishes in the English Channel; but later, as the upper layers are stabilised by becoming less dense when warmed by the absorption of solar radiation, we find a preferential depletion of the upper portion as shown in Fig. 9. Plant growth depends upon adequate illumination, and it became necessary to obtain quantitative measurements in order to follow such development in the sea. Poole's apparatus rendered it possible to extend the measurements of Shelford and Gail, made in

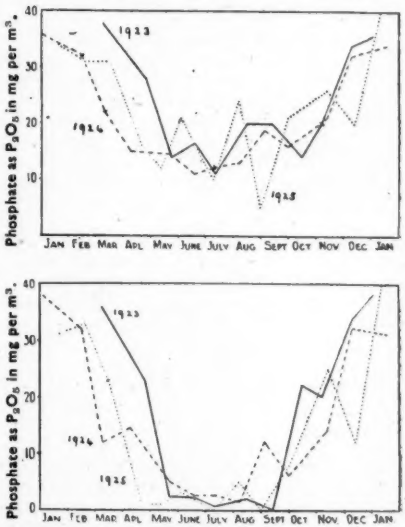


Fig. 9. Relation between phosphates content and month of year. The lower frame gives the yearly changes in surface water at station E1; the upper relates to bottom, 70m.

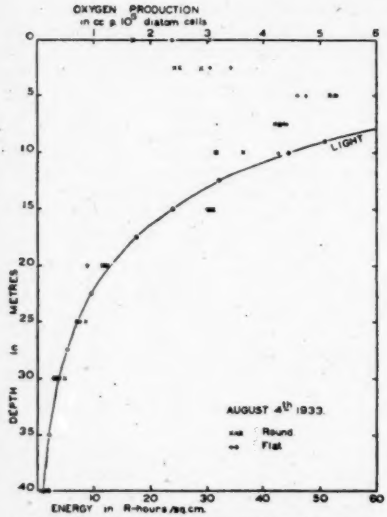


Fig. 10. To show the variation of oxygen production by the diatom Coscinodiscus with the incident light energy.

the calm waters of Puget Sound, right out to the open sea.

From the phosphate used up each year one calculates that the wet weight of the plant substance produced in the English Channel is about 1,400 metric tons per sq. km. down to a depth of 70 metres. Similar values are arrived at by calculating from the carbon dioxide and nitrogen compounds used up and from the oxygen set free in the water.

During the last war the late Sir William Thompson, Professor of Physiology in Trinity College, Dublin, showed that the most economical production of animal food was obtained by feeding pigs on potatoes. A potato yield of 8,000 tons per sq. km. should produce 1,976 pigs, which on a basis of 5 per cent. utilisation means 152 tons of pig per sq. km. Taking the bacon yield at slightly under 3 per cent. we arrive at 97 tons per sq. km. On this 3 per cent. basis 1,400 tons of plant substance might yield 42 tons of animal food, but the utilisation factor is not known for the processes in the sea, which lead from microscopic plants, through minute, shrimp-like animals up to the edible fishes.

We see then that the ocean crops depend, just as on land, upon sunshine and the availability of certain mineral salts. Great fisheries are situated where ocean currents impinge upon banks and the deeper waters well up into the sunlight. This occurs on the banks of Newfoundland and around South Georgia. In shallow seas the annual thermal cycle causes a vertical circulation of the water.

But a plant can have too much light. This was demonstrated for diatoms by the work of Marshall and Orr, and at Plymouth by Miss Jenkin, who by lowering bottles with pure cultures of diatoms found that for a species of Coscinodiscus the maximum production of oxygen was obtained at a depth of 5 metres. When the incident energy was plotted against depth, it was only from about 8 metres downwards that oxygen production was closely proportional to it. At lesser depths, the greater amount of energy resulted in a reduced liberation of oxygen.

The amount of light may also influence the vertical distribution of invertebrates, as shown notably by Russell, who counted the hauls obtained at various depths under different meteorological conditions. In dull weather the copepod Calanus finmarchicus is found mainly close to the surface, whereas under a bright, cloudless sky, it is distributed well down in the water around a level of optimum illumination. Cosmetira pilosella, on the other hand, is found over a narrower range of intensity and mainly at 20-30 metres.

Conclusion.

I have now given you a general outline of the study of illumination in the open, and it is in the open that the human eye was evolved. One may consequently expect that, provided the light is properly diffused, it is under such relatively high illuminations that it will function at its best. One must, however, remember that the diffuse reflection (albedo) of natural objects is low, far lower than that of white paper or textiles, and that when dealing with metallic parts it is difficult to avoid specular reflection. An attempt has also been made to outline very briefly the qualitative and quantitative changes undergone by daylight during its passage through sea water and to indicate why such a study

should be of importance to biologists. As engineers, I take it, that you will not disagree with the postulate that a consideration of the energy available is of primary importance in any undertaking. It remains for me to express the hope that I may be favoured with reprints of any papers dealing with photometry and vision, which you may publish, and that perhaps some of you will find time to visit me at the Marine Biological Laboratory, Plymouth, and give me the benefit of your criticisms and suggestions as I show you the instruments we now use.

Of the figures, six were originally published by the Royal Society, London, and five by the Marine Biological Association, Plymouth, to which I desire to acknowledge my indebtedness.

THE ANNUAL GENERAL MEETING

The annual meeting of the Illuminating Engineering Society took place in the Lecture Theatre in the Institution of Mechanical Engineers, at 4.30 p.m., on Tuesday, May 15, 1945.

Before the commencement of formal business the President (Mr. E. Stroud) made a few remarks expressing the gratitude of members for the victorious conclusion of hostilities in Europe, and read out a congratulatory telegram from the Illuminating Engineering Societies of Australia.

The Hon. Secretary having read the notice convening the meeting and also the statement of the auditors in regard to the accounts for the past year, it was agreed that the minutes of the last meeting, which had been published in THE TRANSACTIONS, should be taken as read.

The President then presented the Report of the Council and statement of accounts for 1944.

Adoption of Report and Accounts

The following resolution was then put to the meeting by Mr. A. Darlington and seconded by Mr. S. D. Lay:—

That the Report of the Council and the accounts of the Illuminating Engineering Society for the period January 1, 1944, to December 31, 1944, be hereby adopted, and that a vote of thanks be extended to the President, Council, and officers for their efforts on behalf of the Society during the past session.

On being put to the meeting the Report was declared carried unanimously.

The President, on behalf of the Officers and Council, expressed his appreciation of the vote of thanks and added that the satisfactory results achieved last year had been due not only to their efforts but also to work done by a considerable number of members in London and the Provinces.

Election of Officers and Council

The President then proceeded to refer to events that had taken place since the period covered by the Report.

In regard to elections for the forthcoming session he stated that no independent nominations for officers had been received. Therefore the Council's nominations stood, and those elected were as follows:—

President: Mr. H. C. Weston.

Vice-Presidents: Mr. Howard Long, Mr. H. E. Chasteney, and Mr. J. M. Waldram.

Hon. Treasurer: Mr. N. V.-Everton.

Hon. Secretary: Mr. J. S. Dow.

The report of the scrutineers of the ballot for members of the Council was

then presented, and it was announced that the following had been elected:—

Members of Council: Mr. J. N. Aldington, Mr. M. G. Bennett, Dr. W. M. Hampton, Mr. A. G. Higgins, Mr. J. S. Preston, Mr. A. J. Pashler, Mr. E. B. Sawyer, Dr. W. S. Stiles, Dr. W. D. Wright.

The scrutineers were thanked for their services.

In presenting the Annual Report, which again contained encouraging evidence of progress, the President drew attention to the progressive Growth in Membership, which now exceeded 1,600, and to the fact that ten Centres and seven Groups were now in operation. Centre status was about to be granted to the recently-formed Groups in Edinburgh and Liverpool, and since the opening of the present year a new Group had been formed in Halifax.

Reference was made to the successful publication of Lighting Reconstruction Pamphlets, now six in number. The most recently issued entitled "Making Work Lighter," dealt with Industrial Lighting, and was illustrated by sketches in colour by Fougasse.

It was recalled that during the past year an increase in subscriptions, to provide for extension of administrative arrangements at Headquarters and to facilitate the development of post-war activities, had been approved by members.

In this connection the Council had appointed, as Secretary of the Society, Mr. Raymond Pye (the Hon. Secretary of the Leeds Centre), who it was hoped would enter upon his duties in July.

It was then proposed by Lieut. B. F. W. Bessemer and seconded by Mr. E. S. Evans:—

> That the meeting records the appreciation of the services of Messrs. Robert J. Ward and Co. as auditors of the Society and approves their re-election for the next session.

This resolution, too, was declared carried unanimously. This terminated the formal business.

Address on Daylight and its Penetration into the Sea

Dr. Atkins opened his address by a review of developments in photo-electric cells, drawing attention to the great gain in sensibility secured during recent years. He also described a device for the measurement of "total daylight," independent of the altitude of the sun, and discussed methods of "integrating" fluctuating illumination (e.g., illumination under waving tree tops. Illustrations of the variation of daylight during the year and in successive years were given.

Subsequently he described researches into the penetration of daylight into sea water, and finally discussed the effect of light upon marine plant life round our coasts.

(A full account of the address appears on pp. 133-143.)

Dr. H. BUCKLEY, in proposing a vote of thanks to Dr. Atkins for his address, said that Dr. Atkins had surveyed in a most stimulating and interesting manner his work in an important field. Although Dr. Atkins had been a member of the Society for several years, members of the Society had not, owing to the war and his distance from London, had the opportunity of meeting him at its meetings before. Most of the members of the Society had some interest in photometry, but in the main they were interested in it as the meterological basis of the applied science of lighting. Dr. Atkins's interest, however, was more fundamental as he was interested in photometry as a means of extending our knowledge of the phenomena of marine life. The Society, Dr. Buckley said, was particularly glad to welcome as members those outside scientists who had wider interests in lighting and its related phenomena than their own.

Dr. Atkins was a most distinguished member of the Marine Biological Laboratory at Plymouth, which was probably the best known of all such laboratories in the world, and was indeed the Mecca of all marine biologists. Dr. Atkins started his work there after a somewhat varied career as a chemist and botanist, which included a short spell at the N.P.L. during the first world

war, and there were still those at the N.P.L. who had pleasant recollections of the tall Irishman who descended upon them for a short time.

At the Marine Biological Laboratory he immediately tackled the problem of harnessing the photoelectric cell to photometry, and had contributed largely to the improvement of the status of photometry from an art associated with a grease-spot to a more or less exact science. His papers were read with great interest by the members of the photometry section at the N.P.L., who were comforted to learn that he experienced the same difficulties as they did, made even more troublesome by the special circumstances in which he worked.

Dr. Atkins, he said, had made the subject of submarine illumination peculiarly his own, so that when at N.P.L. he received inquiries for data on this subject he could do no better than refer his inquirers to Dr. Atkins's work. Dr. Buckley mentioned that in his presidential address he had made reference to the work of Bouguer in the early years of the eighteenth century. Dr. Atkins and Bouguer, he said, had much in common, as they were both interested in problems of daylight illumination and the transmission of sea-water, so that it would appear that the mantle of Bouguer had fallen on the shoulders of Dr. Atkins, who was, if he might say so, wearing it very well indeed.

Mr. J. M. WALDRAM said he was particularly glad of the opportunity to second the vote of thanks, for several reasons, not the least of which was that it gave him the opportunity to acknowledge the help which Dr. Atkins gave to himself and some of his colleagues when they were concerned with problems of lighting under water. Dr. Atkins was then able to give them data which enabled them to solve problems which could not otherwise have been tackled at all. He personally did not then know what a wealth of information Dr. Atkins had accumulated after many years of the study of photometry under unusual circumstances; some of the curves which Dr. Atkins had shown them during his lecture would have been very valuable for several war problems. He was also interested in Dr. Atkins's results since he and some of his colleagues had been doing something similar in the air to what Dr. Atkins had done under the sea.

It was a delightful custom of the Society to invite distinguished men of science to the annual general meeting to talk about subjects with which not many members of the Society were familiar but which was related to illuminating engineering. He felt as though he had been taken for a walk in an unfamiliar part of a wood by somebody who knew it well and then had been brought to a glade which he also knew, though from the other end. Illuminating engineering was not so great a wood as some of the older and more venerable subjects, but it was surrounded by common land which it shared with some very interesting neighbours. They had met on that common the architect, the road-maker, the physicist, the physiological optician, the meteorologist, and others, and now the Society had found common interests with a marine biologist. Dr. Atkins's lecture was not only interesting in itself, but would help them in some special under water lighting problems, such as the lighting of swimming-baths and lighting for certain experimental purposes.

The vote of thanks was passed with hearty acclamation.

Sessional Meeting in London

A Sessional meeting took place at the E.L.M.A. Lighting Service Bureau (2, Savoy-hill, London, W.C.2) at 5.30 p.m. on Wednesday, April 18, 1945. The President (Mr. E. Stroud) was in the chair.

After the Minutes of the previous meeting, which were taken as read, the President called upon Mr. R. Maxted to read the paper entitled "Circuits for Discharge Lamps," which had been prepared by himself and Mr. J. N. Hull.

In the subsequent discussion Mr. J. M. Waldram, Dr. S. English, Mr. A. Cunnington, Mr. F. C. Raphael, Mr. C. R. Bicknell, Mr. W. J. Scott, and Mr. Veness took part.

After Mr. Maxted had briefly replied to the discussion, a vote of thanks to the authors of the paper, and also to E.L.M.A. for their kind hospitality, terminated the proceedings.

Additions to List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

CORPORATE MEMBERS:—

Cartwright, J. T. P. ...Gorseddfa, Brynmawr Avenue, Ammanford, CARM.

Earnshaw, J. A. .....288a, Queen's Road, HALIFAX.

Fry, A. E. .....10, Churchill Avenue, Kenton, MIDDX.

Golland, W. .....Red Stacks, Beacon Drive, Grange, West Kirby, Wirral, CHESHIRE.

Harlow, C. W. .....3, Hydethorpe Avenue, Edmonton, LONDON, N.9.

Hakes, R. W. .....8, Westbury Road, LONDON, N.12.

Hird, W. T. .....Rutland Hotel, Glossop Road, SHEFFIELD, 10.

Hunt, E. .....Electrical Components, Ltd., Church Bank, BRADFORD.

Newnham, G. .....Staff-Sergeants' Mess, R.A.F. Station, Catterick, Nr. Richmond, YORKS.

Richard, S. T. .....Homelands, Betws, Ammanford, CARM.

Stuart, Chas. .....2, John Street, Alexandria, DUMBARTONSHIRE.

Thomas, D. J. .....3, Crichton Street, Treorchy, GLAM.

Thomas, Fredk. .....251, St. Paul's Road, Preston, LANCS.

Tyrrell, D. W. .....60, St. Andrew's Road, Coulsdon, SURREY.

Wylie, A. .....302, Barnsley Road, SHEFFIELD, 4.

STUDENT:—

Algar, Peter H. .....98, St. George's Square, LONDON, S.W.1.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form :—"Trans. Illum. Eng. Soc. (London)."

Printed by ARGUS PRESS, LTD., Temple-avenue and Tudor-street, London, E.C.4, England